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**SMOKE AND CLEAN AIR GENERATING MACHINE FOR  
DETECTING THE PRESENCE AND LOCATION OF  
LEAKS IN A FLUID SYSTEM**

**I N S A I**

**BACKGROUND OF THE INVENTION**

10 1. **Field of the invention.**

This invention relates to a compact, easy to use and portable smoke and clean air generating machine that enables the presence and location of leaks in a fluid system (e.g. the evaporative or brake system of a motor vehicle) to be accurately and visually detected depending upon the rate of air flow through the fluid system under test and whether smoke escapes from the system.

15 2. **Background art.**

Our Patent Application No. 09/020,841 filed February 9, 1998 and entitled SMOKE PRODUCING APPARATUS FOR DETECTING LEAKS IN A FLUID SYSTEM discloses an efficient, portable apparatus for generating smoke in order to locate leaks in a fluid (e.g. air, oil, fuel, exhaust, etc.) system. A supply of oil within a sealed chamber is vaporized, and the resulting smoke is delivered to the system under test. By visually inspecting the system for smoke escaping therefrom, the precise location of a leak in the system can be accurately detected.

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With the growing emphasis being placed on reducing the volume of emissions leaking into the atmosphere, it has become increasingly important to be able to monitor

and test the integrity of a fuel vapor recovery or evaporative system in today's motor vehicles. By way of example, to test for leaks, the evaporative system of a motor vehicle is typically pressurized for a predetermined time. If the pressure holds throughout the time interval, then the integrity of the system is presumed to be intact.

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The problem is that this conventional method of testing for leaks in the vapor recovery system of a motor vehicle does not take into account the volume of fuel stored in the gas tank. That is to say, the smaller the volume of fuel stored in the gas tank, the greater will be the empty space within the tank lying above the fuel supply. Such empty space acts as an air and pressure accumulator. More particularly, for a vehicle with less fuel and a larger air space in its tank, it will take a longer time to detect a leak. Therefore, the test operator can receive a false indication as to the integrity of the evaporative system, because of the increased time that is required for this system having an air accumulator to be fully pressurized. Consequently, an evaporative system which shows that it is holding pressure over time may actually have a leak and be in need of repair to avoid emissions to the atmosphere.

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Accordingly, it is desirable to be able to overcome the aforementioned problems associated with the conventional method of testing for leaks in a fluid system so that the existence and location of a leak may be accurately verified and detected. To this end, it would also be desirable to achieve this goal by using the efficient smoke generating apparatus that is described in our above-entitled patent application.

## SUMMARY OF THE INVENTION

Briefly, and in general terms, a smoke and clean air generating machine is disclosed that is adapted to produce either a supply of clean air or a supply of smoke to a fluid system (e.g. the evaporative or brake system of a motor vehicle) to be tested for leaks. An air compressor provides a supply of air under pressure. The air compressor is connected to supply air to a smoke generating apparatus or to a flow meter by means of a two-way bleed off selector valve. More particularly, with the selector valve rotated to a clean air position, the air compressor will communicate with the flow meter which measures the rate of air being delivered to the system under test. With the selector valve rotated to a smoke position, the air compressor will be connected to the smoke generating apparatus so that a supply of oil in a sealed chamber can be blown towards and vaporized by a heating grid and the resulting smoke delivered to the system under test. However, when the selector valve passes through a center position between its smoke position and clean air position, any pressure that has been developed in the air line between the air compressor and the smoke generating apparatus will be exhausted (i.e. bled off) to the atmosphere so as to automatically de-energize the heating grid of the smoke generating apparatus and thereby insure that the heating grid will cool and no additional smoke will be generated.

In operation, the selector valve is first rotated to its clean air position, whereby a supply of clean (i.e. non-smoky) air is delivered from the air compressor to the system under test via the flow meter. An air accumulator having an integral check valve to relieve excess pressure is located between the selector valve and the flow meter to

smooth any pulsations in the flow of air to the meter. The existence of a leak having sufficient size to require repair is indicated in the event that the flow meter reads a rate of air flow from the air compressor to the system under test which is greater than a predetermined flow rate that is characteristic of a leak free system. Should a leak be  
5 indicated, the selector valve is then rotated to its smoke position, whereby a supply of air is delivered from the air compressor to the smoke generating apparatus. The smoke generating apparatus generates a supply of smoke via a smoke outlet line thereof to the fluid system under test. By visually inspecting the system under test for any escaping smoke, the precise location of a leak can be determined. Coupled to the smoke outlet line  
10 of the smoke generating apparatus is a pressure discharge accumulator having an integral check valve that is adapted to open to relieve excess pressure. In the event of a pressure build-up in the smoke outlet line (such as when the system to be tested is partially or completely restricted), the smoke is diverted to the check valve. As the exiting smoke begins to cool and condense, droplets of oil will be collected within the pressure discharge accumulator. The excess pressure within the smoke outlet line will then be dissipated to the atmosphere through a small orifice in the accumulator.

As an alternate embodiment of the present invention, the air compressor to deliver clean air to the flow meter and the smoke generating apparatus can be replaced by a  
20 pressure and flow regulated source of non-flammable nitrogen gas. In this case, a mixture of nitrogen (rather than air) and smoke will travel through the smoke outlet line to be delivered to the system under test so that a relatively safe, non-explosive

environment can be established, particularly in situations characterized by high temperatures.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a schematic of the smoke and clean air generating machine which forms the present invention for verifying the presence and detecting the location of leaks in a fluid system under test;

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FIG. 2 shows a 2-way selector valve from the smoke and clean air generating machine of FIG. 1 rotated to a clean air position for connecting an air compressor to the fluid system under test by way of a flow meter;

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FIG. 3 illustrates the selector valve of FIG. 2 rotated to a smoke position to connect the air compressor to a smoke generating apparatus; and

FIG. 4 shows the selector valve rotated to a center position between the clean air and smoke positions of FIGS. 2 and 3 for discharging pressure through the selector valve 20 to control the operation of the smoke generating apparatus.

#### DETAILED DESCRIPTION

25 Referring to the drawings, there is shown in FIG. 1 a smoke and clean air generating machine having an outer casing (designated by phantom lines) 50 within which is housed a smoke generating apparatus 1 that is adapted to generate a supply of

smoke to a smoke outlet line 2 and a smoke supply line 4 so that a fluid system (not shown) can be visually inspected for leaks. The smoke generating apparatus 1 has been described in detail in our earlier Patent Application Serial No. 09/020,841 filed February 9, 1998, the teachings of which are incorporated herein by reference. Therefore, a full 5 description of the smoke generating apparatus 1 will not be provided.

10 Briefly, however, the smoke generating apparatus 1 includes a sealed chamber 6 which contains a non-toxic oil supply 8. An air inlet tube 10 projects upwardly from the bottom of chamber 6 and extends above the oil supply 8. Inlet tube 10 communicates with an external air compressor 25 through a wall of chamber 6. An inlet orifice 12 is formed in the air inlet tube 10 so as to lie within the oil supply 8 immediately above the bottom of chamber 6. A resistor heating grid (e.g. coil) 14 extends laterally across the sealed chamber 6 and is electrically connected to a 12 volt battery 16 by means of an electric pressure switch 36. A fluid baffle 18 having a smoke outlet orifice 20 formed therein extends laterally across the sealed chamber 6 above the heating grid 14. The aforementioned smoke outlet line 2 communicates with the outlet orifice 20 through the top wall of the sealed chamber 6.

15 In operation, when the pressure switch 36 is closed, the battery 16 supplies current to heat the heating grid 14, and the air compressor 25 delivers air into the sealed chamber 6 via air inlet tube 10 at approximately 14 liters/minute to cause some of the oil supply 8 within the chamber to be drawn, by means of suction through inlet orifice 12 and into the air inlet tube 10. A mixture of air and oil is then blown upwardly and

outwardly from the air inlet tube 10 towards and into contact with the heating grid 18, whereby the oil is instantaneously vaporized into smoke. The rising smoke travels through the outlet orifice 20 in fluid baffle 18 for receipt by the smoke outlet line 2. Accordingly, the smoke in outlet line 2 is carried by way of the smoke supply line 4 to 5 the fluid system to be tested so that the integrity of the system may be visually inspected for leaks depending upon the absence or presence of smoke escaping therefrom.

In accordance with the present improvement, a two-way never closing bleed-off selector valve 30 is provided to control the flow of air from the compressor 25 to either 10 the smoke generating apparatus 1, when it is desirable to generate smoke to be delivered to the system to be tested for leaks, or to a flow meter 32, when it is desirable to supply clean (i.e. non-smoky) air to the system to be tested. The selector valve 30 is rotated to a clean air position to connect the air compressor 25 to the flow meter 32, whereby clean air will by-pass the smoke generating apparatus 1 for receipt by the system to be tested 15 via the smoke supply line 4 when it is desirable to verify the existence and size of a potential leak in the system. Since smoke carries oil and particulate matter, it is not desirable for smoke to pass through the flow meter 32. Such smoke can cause the flow meter 32 to malfunction and eventually fail.

20 The selector valve 30 is rotated to a smoke position to cause the air compressor 25 to communicate directly with the smoke generating apparatus 1, whereby smoke can be generated to identify the specific location of a leak in the system to be tested. As will be described in greater detail hereinafter when referring to FIG. 2-4, the selector valve 30 is

also rotated to a center position (i.e. during the transition between the smoke and clean air positions) when it is desirable to bleed-off pressure that has been developed in the smoke outlet line 2 by the air compressor 25.

5 With the selector valve 30 rotated to the smoke position to connect the air compressor 25 to the smoke generating apparatus 1, air, under pressure, will be supplied to the air inlet tube 10 inside the sealed chamber 6 by way of a seven pound cracking pressure check valve 34. Pressure check valve 34 performs two different functions. In one case, the pressure check valve 34 functions as a conventional one-way check valve to block the reverse flow of oil from the smoke generating apparatus 1 to the selector valve 30. In addition, check valve 34 also prevents the backflow of oil from chamber 6 should the casing 50 be accidentally tipped. In a second case, the pressure check valve 34 establishes a back pressure in the air supply line between check valve 34 and air compressor 25. Such back pressure is required to activate the aforementioned electric pressure switch 36 which is connected to the battery 16 and which must be closed before current will be supplied from battery 16 to the heating grid 14 within the chamber 6 of smoke generating apparatus 1.

20 The electric pressure switch 36 is a conventional, normally open pressure activated contact switch. When the selector valve 30 is rotated to its smoke position, the normally open electric pressure switch 36 will be closed in response to the pressure that is established in the line between check valve 34 and air compressor 25. Once switch 36 is closed, a current path will be created between the battery 16 and the heating grid 14 of

smoke generating apparatus 1 so that the droplets of oil that are blown towards heating grid 14 from oil supply 8 will be vaporized into smoke within chamber 6. However, as an important feature of this invention, when the selector valve 30 is rotated from its smoke position so as to move through the center position thereof (best described when referring to FIG. 4), an air path will be created through selector valve 30 by which to relieve the back pressure that was previously established behind check valve 34. In particular, such back pressure will be discharged through selector valve 30 to the air compressor 25 or to a soon to be described air accumulator 42. Hence, the electric pressure switch 36 will be responsive to such pressure loss, whereby to automatically return to its normally open switch condition and thereby break the current path between the battery 16 and the heating grid 14 of smoke generating apparatus 1. Accordingly, the heating grid 14 will cool and the generation of smoke will cease.

As another important feature of this invention, the smoke outlet line 2 from the sealed chamber 6 of smoke generating apparatus 1 is coupled to a pressure discharge accumulator 38 through a one pound cracking pressure check valve 40. As shown, the pressure check valve 40 is positioned upstream and between the smoke generating apparatus 1 and the system to be tested so as to be responsive to the output pressure of the smoke that is carried by the smoke outlet line 2 after selector valve 30 has been rotated to its smoke position. By virtue of the foregoing, when the smoke supply line 4 or the fluid system to be tested is partially or fully restricted, the pressure check valve 40 will open, whereby smoke and/or pressure that builds up within the smoke supply line 4 will be able to escape to the atmosphere through an orifice in the pressure discharge accumulator 38.

At the same time, the open pressure check valve 40 will allow air (including any oil products that are carried therein) to continue to circulate through the chamber 6 of smoke generating apparatus 1 in order to produce smoke therewithin. Such continued circulation will advantageously prevent the heating grid 14 of smoke generating apparatus 1 from overheating at times when the system to be tested is blocked and smoke within the outlet line 2 would otherwise be trapped.

Locating the pressure check valve 40 after the smoke producing apparatus 1, rather than prior to the air inlet tube 10 of chamber 6 (e.g. between inlet tube 10 and pressure check valve 34), avoids an early release of some or all of the pressure which would reduce or eliminate the air and oil circulation process that is otherwise achieved in the manner described above by coupling the smoke outlet line from chamber 6 to the pressure check valve 40. Thus, with the present improvement, it will still be possible to generate smoke so as to locate any leaks in the fluid system to be tested even during situations where the fluid system and/or the smoke supply line 4 is partially or completely restricted.

Locating the combination of pressure discharge accumulator 38 and pressure check valve 40 upstream from the smoke generating apparatus 1 will permit any oil products that have been vaporized by the heating grid 14 and carried through an open check valve 40 to condense and collect within the accumulator 38 during less than full flow conditions in the smoke outlet line 2. Such condensation reduces the amount of unwanted oil that would otherwise be released into the environment from the pressure

discharge accumulator 38 under abnormally high pressure conditions within the smoke outlet line 2 when the pressure check valve 40 is open. In other words, accumulator 38 collects the residue after the oil supply 8 from sealed container 6 is first vaporized by heating grid 14 into smoke and then condensed back into oil following contact with check valve 40. Without accumulator 38 to collect the oil residue, the oil carried by the smoke could build up on the outlet side of the pressure check valve 40 and eventually spill out each time that the check valve 40 would open to release pressure. Such oil spillage could be undesirably encountered at the exterior of the casing 50 in which the smoke generating apparatus 1, selector valve 30 and pressure check valve 40 are all housed and transported from place to place.

At such time when the selector valve 30 is rotated to its clean air position (when no smoke is being generated by apparatus 1), an air path is established between compressor 25 and a pre-meter air accumulator 42. Air accumulator 42 is preferably a hollow chamber or air damper that functions to reduce or dampen the fluctuation to which flow meter 32 would be subjected that might alter the reading of flow meter 32 as a consequence of the pulsations that are common to a piston-type air compressor, such as that which has been shown and described herein, and the opening and closing of a soon to be described check valve 44. In this same regard, it would be possible to eliminate the air 20 accumulator 42 altogether if the air compressor 25 were replaced by a non-pulsating air pump. However, a pulsating piston-type air compressor 25 is preferable because it is known to be reliable and readily available for use in the present invention.

A one-half pound check valve 44 is coupled to the air accumulator 42. Check valve 44 functions to relieve excess pressure within the clean air supply line 46 when clean air is supplied via flow meter 32 and the system to be tested or the smoke supply line 4 is partially or fully restricted. It is important that the check valve 44 be positioned 5 behind (i.e. downstream from) the flow meter 32. During clean air operation, with selector valve 30 rotated to its clean air position, if check valve 44 were located ahead of (i.e. upstream from) flow meter 32, then the flow meter 32 would continue to meter clean air passing therethrough even if the system to be tested or the smoke supply line 4 were blocked.

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Connected in the clean air supply line 46 which runs from flow meter 32 to smoke supply line 4 is a directional check valve 48. Check valve 48 limits the flow of clean air from air compressor 25 to a single direction away from flow meter 32 so that smoke produced by smoke generating apparatus 1 will be unable to pass through the clean air supply line 46 to contaminate the flow meter 32 and loose pressure through check valve 44 which would undesirably reduce the efficiency of operation.

On the other hand, to maximize the efficiency of the smoke and clean air generating machine of this invention, it is important that the check valve 44 on the clean 20 air side have a lower cracking or threshold pressure (e.g. one-half pound) than the cracking pressure (e.g. one pound) of the check valve 40 on the smoke side. As previously described, if the system to be tested or the smoke supply line 4 were partially or completely restricted after selector valve 30 is rotated to its clean air position, any

excess pressure that is built up in the clean air supply line 46 would escape through check valve 44 of air accumulator 42. However, if the cracking pressure of check valve 40 were less than the cracking pressure of check valve 44, then flow meter 32 will continue to meter air flow therethrough even during such high pressure conditions. By virtue of 5 the present improvement, if the system to be tested or the smoke supply line 4 were blocked when the selector valve 30 is rotated to its smoke position, then the smoke generated by apparatus 1 will escape through check valve 40, since the directional check valve 48 will not allow the back flow of smoke through the clean air supply line 46 and towards flow meter 32.

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Although the smoke generating apparatus 1 has been described above as receiving air under pressure from an air compressor 25, it is to be understood that gases other than air may be supplied to the air inlet tube 10 of apparatus 1 to cause a mixture of such gas and oil to be blown towards the heating grid 14. More particularly, testing the integrity of the evaporative system in a motor vehicle is now required by the Environmental Protection Agency in many states. It has become essential to be able to verify if the evaporative system has a leak and then identify the location of the leak. As an alternative to pressurized air, carbon dioxide or nitrogen gas from a pressure and flow regulated tank or bottle 60 can be used because of their non-flammable and inert characteristics. That is 20 to say, smoke carried by nitrogen gas would be relatively safe for testing the evaporative system of a motor vehicle which lies in a generally volatile environment of potentially explosive hydrocarbon vapors. Accordingly, the ability to produce smoke with nitrogen gas would provide a safe and efficient means for locating a leak in the evaporative system

of a motor vehicle. Moreover, producing smoke with nitrogen gas rather than air would enable a variety of high pressure systems (e.g. an air brake system) to be tested at high operating temperatures but without the inherent risks of an explosion.

5        What is even more, other sources of air under pressure, other than air compressor  
25, may be employed to blow the oil towards the heating grid 14. For example, conventional shop air such as that used by an automotive repair facility may be substituted for compressor 25.

10       The advantage provided by the smoke and clean air generating machine of this invention is not only the ability to indicate the precise location of a leak (when selector switch 30 is rotated to the smoke position), but also to first verify whether the system to be tested has a leak in need of repair (when selector switch 30 is rotated to the clean air position). More particularly, the flow meter 32 that is connected in the clean air supply line 46 is a non-regulating flow meter that has a ball indicator to provide a visual reading when the system to be tested has a leak that is of sufficient size to warrant repair. Flow meter 32 is first initialized to a flow rate setting that corresponds to a leak size in the fluid system of 1 millimeter in diameter, a size which is generally considered in the industry to represent the standard tolerance level of a fluid system before the repair of a leak is  
15       required. Of course, the initial setting of flow meter 32 could change in the event that the tolerance standards of fluid systems subjected to leaks also change.  
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Once the selector valve 30 is rotated to its clean air position to connect air compressor 25 to flow meter 32, should the fluid system have a leak size which is in tolerance (i.e. less than 1 millimeter) then the reading of flow meter 32 will be at or below the initialized flow rate, and no repair will be necessary. However, should the 5 fluid system have a leak, the size of which is larger than 1 millimeter, then the reading of flow meter 32 will be above the initialized flow rate, such that the leak must be located and repaired. At this point, the selector valve 30 is rotated from its clean air position to its smoke position, whereby a supply of smoke is delivered from the sealed chamber 6 of smoke generating apparatus 1 to the system to be tested in the manner described above.

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Turning now to FIGs. 2-4 of the drawings, details of the 2-way bleed-off selector valve 30 are now provided. FIG. 2 shows the selector valve 30 having a manually controlled knob 50 rotated to the clean air position in order to connect the air compressor 25 to the clean air side of the smoke and clean air generating machine of this invention so that a supply of clean air will be delivered to the system under test via the flow meter 32 in order to verify the presence of a leak having sufficient size to warrant repair. In this same regard, the air compressor 25 is disconnected from the smoke generating apparatus 1.

20 FIG. 3 shows the knob 52 of selector valve 30 rotated 180 degrees from the clean air position of FIG. 2 to the smoke position to connect the air compressor 25 to the smoke side of the smoke and clean air generating machine so that a supply of air will be delivered to the smoke generating apparatus 1. Smoke generated from the sealed

chamber 6 of apparatus 1 is supplied to the system under test via smoke outlet line 2 in order to detect the precise location of the leak in need of repair depending upon a visual observation of smoke escaping through the leak. In this same regard, the air compressor 25 is disconnected from the flow meter 32.

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FIG. 4 shows the knob 52 of selector valve 30 momentarily rotated through a center or neutral position during the transition of knob 52 from the smoke position of FIG. 3 to the clean air position of FIG. 2. In this case, an air path is established through selector valve 30 from the check valve 34 to the air compressor 25 and/or the air 10<sub>5</sub> accumulator 42 in order to bleed off air pressure from pressure switch 36. As previously described, pressure switch 36 is responsive to such pressure loss and will return to its normally closed condition, whereby to disconnect the battery 16 from the heating grid 14 of smoke generating apparatus 1 so as to allow the heating grid to safely cool and thereby terminate the generation of smoke.

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It may be appreciated that in a conventional selector valve, the center position thereof would typically allow no air to flow in either direction through the valve. However, selector valve 30 of the present invention is a never closing valve such that in its center position, the smoke side of the smoke and clean air generating machine is 20 momentarily placed into communication with the clean air side whereby air pressure will be bled from the smoke side to cause a drop in pressure so that heating grid 14 will cool and no smoke will be generated. As described above, such bleeding off of the air pressure from the smoke side occurs only when selector valve 30 is moved through its

center or neutral position and, unlike conventional valves, permits the aforementioned communication between the smoke and clean air sides to disconnect heating grid 14 from battery 16.

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WE CLAIM:

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